AD-A091 905 VIRGINIA UNIV CHARLOTTESVILLE DEPT OF MECHANICAL AND--ETC F/G 21/5
NONLINEAR ANALYSIS OF SQUEEZE FILM DAMPERS APPLIED TO GAS TURBI--ETC(U)
NOV 80 E J GUNTER, L E BARRETT, P E ALLAIRE DAA629-77-C-0009
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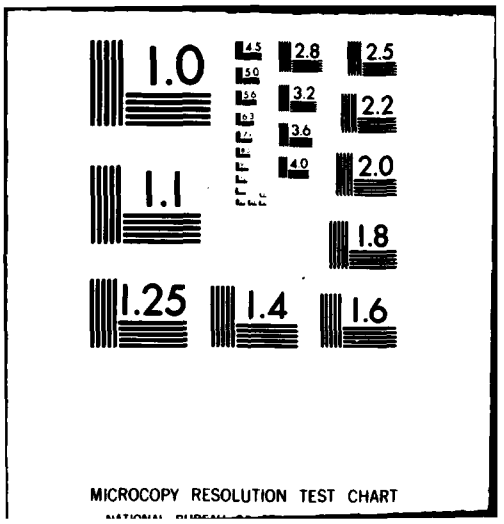
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AD A091905

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: 14166.1-E	2. GOVT ACCESSION NO: AD-A091905
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): Nonlinear Analysis of Squeeze Film Dampers Applied to Gas Turbine Helicopter Engines.	5. TYPE OF REPORT & PERIOD COVERED: Final Report. 15 Jan 77 — 31 May 80
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): E. J. Gunter, L. E. Barrett, P. E. Allaire	8. CONTRACT OR GRANT NUMBER(s): DAAG29-77-C-0009
9. PERFORMING ORGANIZATION NAME AND ADDRESS: University of Virginia, Charlottesville, VA 22901	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: U. S. Army Research Office, Post Office Box 12211, Research Triangle Park, NC 27709	12. REPORT DATE: Nov 80
	13. NUMBER OF PAGES: 11
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): ARO	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

LEVEL II

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

DTIC ELECTE NOV 20 1980 D

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

NA

18. SUPPLEMENTARY NOTES

The view, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other documentation.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

helicopter rotors
rotor balancing
squeeze film dampers
squeeze film bearings
helicopters
helicopter engines
gas turbine helicopter engines
rotors

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Application of the finite length correction factor for the analysis of finite length squeeze film bearings has been made, and a method has been found to be highly efficient. The modal transient program, to include linear rotor acceleration, has been developed and various analysis of rotor systems has been done. A rapid method to calculate the load capacity and dynamics characteristics of a journal or squeeze film bearing has been developed using a finite element approach coupled with an end leakage correction factor. A procedure has been developed to balance

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20. ABSTRACT CONTINUED

a multi-stage turbine without having to first apply trial weights to generate a set of influence coefficients. This procedure represents a major advance in the technology of flexible rotor balancing. It is incorporated into a mini computer system which can collect and analyze the rotor data.

FINAL REPORT

1. ARO PROPOSAL NUMBER: DRX-RO-PR-P-14100-EX

2. PERIOD COVERED BY REPORT: July 1, 1978 - September 31, 1980

3. TITLE OF PROPOSAL: Nonlinear Analysis of Squeeze Film Dampers Applied to Gas Turbine Helicopter Engines

4. CONTRACT OR GRANT NUMBER: DAAG 29-77-C-0009

5. NAME OF INSTITUTION: Department of Mechanical and Aerospace Engineering, University of Virginia

6. AUTHOR(S) OF REPORT: E. J. Gunter, L. E. Barrett, P. E. Allaire

7. LIST OF MANUSCRIPTS SUBMITTED OR PUBLISHED UNDER ARO SPONSORSHIP DURING THIS PERIOD, INCLUDING JOURNAL REFERENCES: See enclosed list.

8. SCIENTIFIC PERSONNEL SUPPORTED BY THIS PROJECT AND DEGREES AWARDED DURING THIS REPORTING PERIOD:

   E. J. Gunter

   P. E. Allaire

   L. E. Barrett - Ph.D. Degree awarded 8/78

   D. F. Li - Ph.D. Degree awarded 12/78

   M. A. Simpson - M.S. Degree awarded 12/78

   R. H. Schmaus - M.S. Degree awarded 9/80

   W. R. Jones - M.S. Degree awarded 9/80

BRIEF OUTLINE OF RESEARCH FINDINGS

1. ANALYTICAL INVESTIGATION

a) The application of the finite length correction factor for the analysis of finite length squeeze film bearings has been made (see section 7). The method has been found to be highly efficient in calculating nonlinear forces for time transient simulations for bearing $0 \leq L/D \leq 1.25$.

b) The digital Fast Fourier Transform analysis has been incorporated in the previous progress reports and a spectral plot of the digital transient data can be generated using an off-line Calcomp plotter.

c) The modal transient program, to include linear rotor acceleration, has been developed and various analysis of rotor systems has been done.

d) Dual level undamped critical speed and rotor unbalance response computer programs have been developed including nonlinear amplitude dependent circular orbit squeeze film bearing forces. These programs are currently being used to examine the response of multi-rotor helicopter gas turbine engine configurations with squeeze film bearings.

e) Dual level damped eigenvalue program has been developed to calculate the stability (complex roots) of a multi-level gas turbine with aerodynamic excitation. This program has been applied to the space shuttle turbopump and has shown major resonance frequencies in the operating range.

f) A rapid method to calculate the load capacity and dynamics characteristics of a journal or squeeze film bearing has been developed using a finite element approach coupled with an end leakage correction factor.

g) A procedure has been developed to balance a multi-stage turbine without having to first apply trial weights to generate a set of influence coefficients. This procedure represents a major advance in the technology of flexible rotor balancing. It is incorporated into a mini computer system which can collect and analyze the rotor data.

2. EXPERIMENTAL INVESTIGATION

A study of the vibration suppression capability of a squeeze film bearing for a small rotor rig has been completed. This rig incorporated an instability mechanism in the form of a plain pressurized journal bearing. The squeeze film bearing reduced resonant vibration amplitudes and completely suppressed unstable vibration modes inherent without the squeeze film bearing. A comparison of theoretical-experimental response results was made and the synchronous response theoretical predictions were in close agreement with the observed experimental response.

A study was conducted on the effect of unbalance levels on the lift-off capability of a statically unsupported squeeze film bearing. The results indicate that significant lift-off will not occur for reasonable rotor unbalance levels if the unbalance is located a large distance from the squeeze film bearing. However, even with small squeeze journal motion, substantial reduction in vibration amplitude can be achieved compared to the rigid bearing response.

A study on the lift-off capability of unsupported squeeze film bearing journals has shown that signiciant lift-off will not occur if fluid film cavitation does not occur. However, substantial rotor damping, even for small journal orbital motion can be achieved. Correlations between predicted and experimental rotor unbalance amplification factors show good agreement for the cases studied.

A new experimental test rotor has been designed to incorporate squeeze film bearings. This rig has destabilizing journal bearings supporting the shaft. Squeeze film bearings have been designed using the results of and design methods developed in previous phases of ARO Sponsorship. The test rotor is 44 in. long, 2.5 in. diameter, and total shaft and impeller weight is 340 lb.

A set of squeeze film bearings have been designed for the Centritech rotor. These damper-bearings have been designed to eliminate hydrodynamically generated instability in the rig and to examine the effects of preload, clearance, supply pressure and retainer stiffness of the dynamic response. Dynamic simulation computer codes have been utilized to predict the nonlinear response of the system for a range of squeeze film parameters which should provide measureable response changes in the test rig. The parameters have been selected to provide instability onset speeds within the operating speed range of the rig to examine and compare predicted and actual upper limits to stable operating regions for the parameter values.

A computer data acquisitions system has been obtained through equipment contributions by the Bently Nevada Corp. and the Phillips Oil Co. The data acquisition system consists of a HP 9845B computer with 187,000 Bytes of memory. The computer is interfaced with the Bently Nevada Digital Signal Tracking filter, and an HP system analyzer.

With the computer system, one can collect and plot nonsynchronous (total motion) as well as the synchronous motion from any of the vibration monitoring probes.. A new balancing procedure has been developed, which utilizes the mini computer system, which can be used for balancing the rotor without having to first resort to the use of trial weights to determine the influence coefficients on the shaft. This procedure appears to be a significant advancement in the state-of-the-art of balancing high speed flexible rotors.

FAST FOURIER TRANSFORM ANALYSIS OF ROTOR-BEARING SYSTEMS

By

K. C. Choy, Post Doctoral Fellow
E. J. Gunter, Professor
P. E. Allaire, Associate Professor

Department of Mechanical and Aerospace Engineering
School of Engineering and Applied Science
University of Virginia
Charlottesville, Virginia 22901

ABSTRACT

Nonlinear transient analysis of rotor-bearing systems is becoming increasingly important in the analysis of modern-day rotating machinery to model such phenomena as oil film whirl. This paper devlops an analysis technique incorporating modal analysis and fast Fourier transform techniques to analyze rotors with residual shaft bow and realistic nonlinear bearings. The technique is demonstrated on single-mass and three-mass rotor examples. Comparisons of the theoretical results with experimental data give excellent agreement.

ASME Topics in Fluid Film Bearings and Rotor Bearing Design and Optimization, 1978

A FINITE LENGTH BEARING CORRECTION FACTOR FOR SHORT BEARING THEORY

By

L. E. Barrett, Research Assistant Professor
P. E. Allaire, Associate Professor
E. J. Gunter, Professor

Department of Mechanical and Aerospace Engineering
School of Engineering and Applied Science
University of Virginia
Charlottesville, Virginia 22901

ABSTRACT

A rapid method for calculating the general nonlinear response of finite-length plain journal and squeeze film damper bearings is presented. The method incorporates a finite-length correction factor which modifies the nonlinear forces obtained from short bearing theory. The steady-state rotational, precessive squeeze, and radial squeeze forces obtained with the correction factor compare extremely well with the forces obtained from an analytic solution of Reynolds equation using a variational approach up to L/D of 1.25 and hence covers the most commonly encountered L/D ratios. The method is no more time consuming than the short bearing analysis and is especially suited to nonlinear transient analysis of flexible rotors.

ASME Topics in Fluid Film Bearings and Rotor Bearing Design and Optimization, 1978

SUPPRESSION OF SELF-EXCITED INSTABILITY USING A SQUEEZE FILM BEARING

By

M. A. Simpson
Research Engineer

L. E. Barrett
Reserach Assistant Professor

Department of Mechanical and Aerospace Engineering
School of Engineering and Applied Science
University of Virginia
Charlottesville, Virginia 22901

ABSTRACT

This work demonstrates the design and application of a squeeze film damper for a single mass flexible rotor in journal bearings including before application and after application expermental results. It is shown that the damper is extremely effective at eliminating subsycnrhonous vibrations due to self-excited instability despite the presence of large instability mechanisms. Cavitation was observed through a clear plastic damper housing. No uniform cavitation region was formed, although isolated bubbles appeared in the fluid at high unbalance levels.

Proceedings on the Conference on the Stability and Dynamic Response of Rotors with Squeeze Film Bearings, May 8-10, 1979, U.S. Army Research Office

ANALYTICAL NONLINEAR BEARING CALCULATIONS USING A VARIATIONAL APPROACH

By

L. E. Barrett

D. F. Li

P. E. Allaire

"Second International Conference on Vibrations in Rotating Machinery," September 2-5, 1980, Churchill College, Cambridge University, Cambridge, England, UK

SYNOPSIS

A solution to the variational equivalent of Reynolds equation for finite length plain cylindrical and segmented journal bearings is presented. An infinite trigonometric series expansion of the pressure field is assumed and the expansion coefficients are found by minimization of the variational principle. The method is intended for use in nonlinear time transient simulations of rotor-bearing systems where finite difference and finite element solutions are computationally too costly to be employed.

A DESIGN METHOD FOR AERODYNAMICALLY EXCITED ROTORS WITH SQUEEZE FILM BEARINGS

By

L. E. Barrett
Research Assistant Professor

Department of Mechancial and Aerospace Engineering
School of Engineering and Applied Science
University of Virginia
Charlottesville, Virginia 22901

ABSTRACT

A linear design method for the design of squeeze film bearings is presented. The method includes the effects of hydrodynamic journal bearings, shaft flexibility and aerodynamic rotor excitation. Linear optimal damping relationships are used to determine retainer spring coefficients and squeeze film damping coefficients. The method is used to design squeeze film bearings for an 8-stage centrifugal compressor with aerodynamic excitation subject to prescribe unbalance response and stability specifications. A nonlinear response and transient analysis of the system shows that the linear design technique provides a viable solution which can be used as a preliminary design aid.

Proceedings of the Conference on the Stability and Dynamic Response of Rotors with Squeeze Film Bearings," May 8-10, 1979.

DYNAMIC CHARACTERISTICS OF A TWO-SPOOL GAS TURBINE HELICOPTER ENGINE

By

E. J. Gunter, Professor*
D. F. Li, Associate Senior Research Engineer**
L. E. Barrett, Research Assistant Professor *

*Department of Mechanical and Aerospace Engineering
University of Virginia
Charlottesville, Virginia

**General Motors Research Laboratories
Warren, Michigan

ABSTRACT

This paper presents a dynamic analysis of a two-spool gas turbine helicopter engine incorporating intershaft rolling element bearings between the gas generator and power turbine rotors. The analysis includes the nonlinear effects of a squeeze film bearing incorporated on the gas generator rotor. The analysis includes critical speeds and forced response of the system and indicates that substantial dynamic loads may be imposed on the intershaft bearings and main bearing supports with an improperly designed squeeze film bearing. A comparison of theoretical and experimental gas generator rotor response is presented illustrating the nonlinear characteristics of the squeeze film bearing. It was found that large intershaft bearing forces may occur even though the engine is not operating at a resonant condition.

Proceedings of the Conference on the Stability and Dynamic Response of Rotors with Squeeze Film Bearings, May 8-10, 1979, U.S. Army Research Office

STABILIZATION OF AERODYNAMICALLY EXCITED TURBOMACHINERY WITH HYDRODYNAMIC JOURNAL BEARINGS AND SUPPORTS*

Lloyd E. Barrett and Edgar J. Gunter
Department of Mechanical and Aerospace Engineering
University of Virginia
Charlottesville, Virginia 22901

Summary

A method of analyzing the first mode stability and unbalance response of multimass flexible rotors is presented whereby the multimass system is modeled as an equivalent single mass modal model including the effects of rotor flexibility, general linearized hydrodynamic journal bearings, squeeze film bearing supports and rotor aerodynamic cross coupling. Expressions for optimum bearing and support damping are presented for both stability and unbalance response. The method is intended to be used as a preliminary design tool to quickly ascertain the effects of bearing and support changes on rotor-bearing system performance.

Proceedings of the Workshop on Rotordynamic Instability Problems in High-Performance Turbomachinery, NASA Conference Publication 2133, Texas A&M University, May 12-14, 1980

UNBALANCE RESPONSE OF A TWO-SPOOL GAS TURBINE ENGINE WITH SQUEEZE FILM DAMPERS

By

E. J. Gunter, Professor*

D. F. Li, Associate Senior Research Engineer**

L. E. Barrett, Research Assistant Professor*

*Department of Mechanical and Aerospace Engineering
University of Virginia
Charlottesville, Virginia

**General Motors Research Laboratories
Warren, Michigan

ABSTRACT

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Submitted to ASME Transactions, 1981 Gas Turbine Conference, Houston, Texas, May 1981.